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Development of a Coal By-Product Classification Protocol for Utilization Task 5.8

Topical Report
January - September 1995

Bruce A. Dockter
Debra F. Pflughoeft-Hassett

October 1995

Work Performed Under Contract No.: DE-FC21-93MC30097

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
University of North Dakota
Energy & Environmental Research Center
Grand Forks, North Dakota

DISCLAIMER

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TASK 5.8 – DEVELOPMENT OF A COAL BY-PRODUCT CLASSIFICATION PROTOCOL FOR UTILIZATION

1.0 INTRODUCTION

A large volume of fly ash is produced that does not meet current American Society for Testing and Materials (ASTM) specifications for use in the production of cement and concrete but could be used for other applications. In many cases, coal ash is required to meet ASTM specifications even when they are clearly inappropriate for the application (i.e., structural fill).

Creating a classification system for fly ash that facilitates the use of performance-based specifications for use applications will broaden the utilization options for coal ash, resulting in avoided disposal costs and opportunities for industry to develop new products and expand the use of coal ash in existing products. The inadequacy of the current classification system is one of the major technical barriers to increased coal by-product utilization. This project is ideally suited to the Energy & Environmental Research Center (EERC) multidisciplinary approach and would involve personnel from several groups.

2.0 GOALS AND OBJECTIVES

The scope of work for this task was limited to the development of a general process to evaluate coal fly ash for use in applications beyond cement and concrete. Two coal fly ash samples were evaluated for appropriateness in structural fill as an example of how to use alternative classification protocol as ash use standards are developed for the industry.

The goal of this project is to develop a classification system for fly ash based on parameters that relate to performance specification of engineering and construction applications. The new classification system will provide a means of evaluating the suitability of coal ash for use in certain products that currently have no reality-based standards or classifications.

3.0 ACCOMPLISHMENTS

Recent work by the ASTM Committee E50 on Pollution Prevention has proposed a standard practice for use of coal ash for structural fill applications. EERC coal ash researchers have worked on preparing this standard practice, and the development of criteria for the coal ash to be used in this application will facilitate the use of this standard once approved by ASTM. A preliminary flowchart for classification criteria was developed and is shown in figure 1.

Structural fill falls within the engineering category under the alternative utilization applications. For structural fill the regulatory and engineerng critera are listed below:

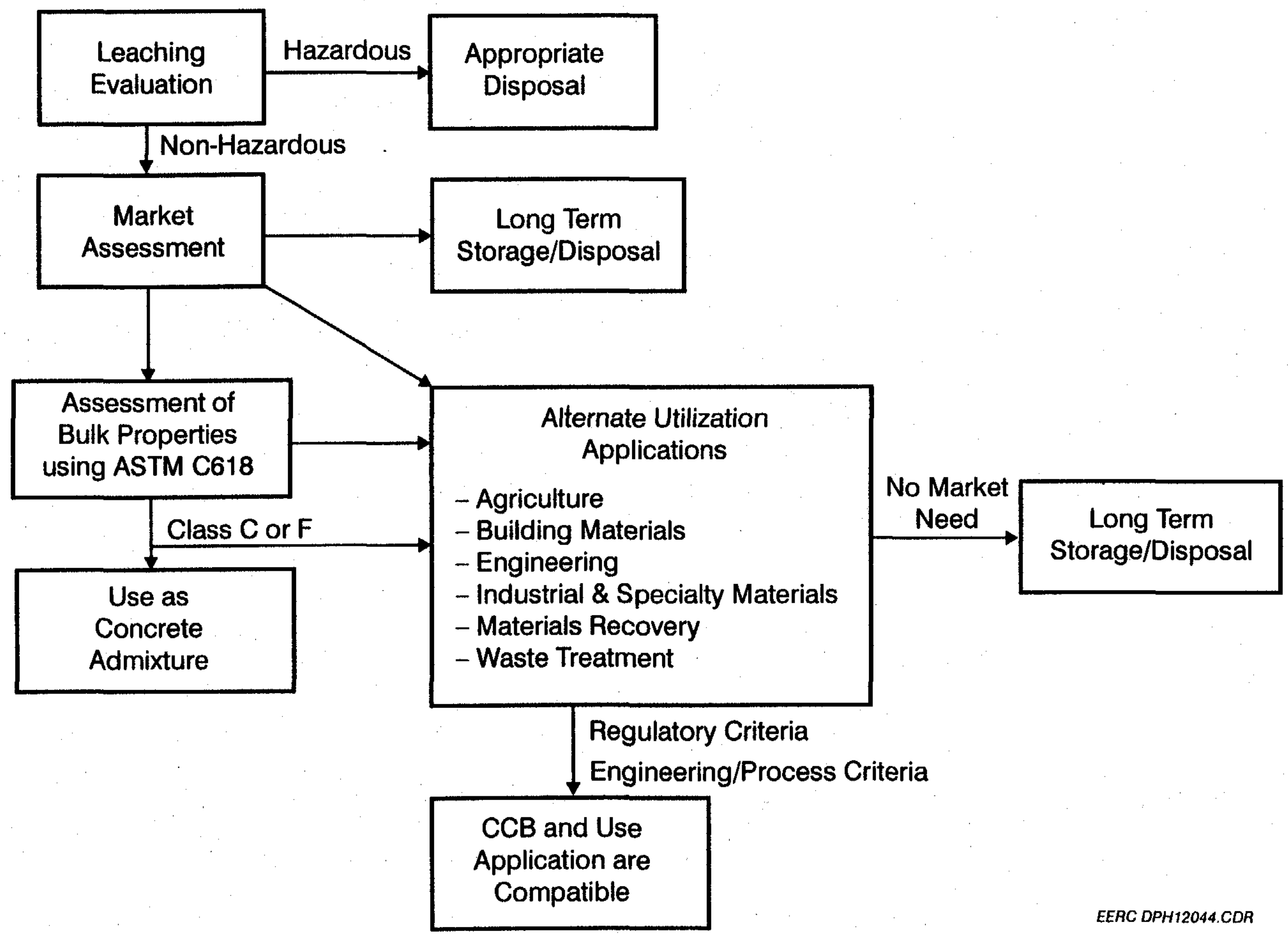

Figure 1. Flow chart for classification of fly ash for utilization.

Regulatory Criteria:
- Regulatory framework
- Water quality
- Surface water
- Radionuclides
- Dust control
- Environmental testing & leaching

Engineering Criteria:
- Grain-size distribution
- Specific gravity
- Moisture content
- Moisture–density relationships
- Shear strength
- Compressibility
- Chemical characteristics (bulk chemistry, pH, resistivity, sulfate)

The prescribed environmental testing is site specific and is beyond the scope of effort for this report. Therefore only a few of the engineering test parameters were used for classification. In general, coal fly ash is an excellent material for the construction of engineered, structural fills. Fly ash is used as structural fill for residential and commercial building sites, embankments for highways and railroads, dikes, and levees, for ecoscreens, and in any other application requiring a compacted fill material. Its low unit weight, relatively high shear strength, ease of handling, and compaction all make it useful as a fill material. Also, because fly ash is an abundantly produced by-product, its use in large-volume applications such as in the construction of structural fills provides an environmentally sound outlet for excess material that may otherwise be disposed when not used on other commercial applications.

Fly ash is typically a relatively uniform, silty-sized material and behaves similarly to natural, cohesionless silty soils, although the cementitious ashes will solidify over time. However, fly ash has a lower specific gravity than most natural soils and primarily consists of spherical particles. These qualities, along with its cohesionless nature, result in certain properties and behavior that differ from other commonly used fill materials.

Fly ash has a low dry density, typically about 50–100 pcf (lb/ft^3). The low density of fly ash fills will reduce the load on weak layers or zones of soft foundation soil. This property is advantageous at sites where poor foundation soils exist or in landslide-prone areas. The low density of fly ash will also reduce transportation costs since less tonnage of material is hauled to fill a given volume. Experience has shown that a fly ash fill consolidates quickly under its own weight, with nearly all of the potential settlement occurring during construction. Relatively little settlement occurs following construction because the resulting low compressibility of the fill and the relatively high permeability of the fly ash allow excess pore water to dissipate rapidly.

Two sources of regional coal fly ash were chosen for laboratory testing for appropriate test procedures. Both sources of fly ash were produced in North Dakota at electric power stations burning North Dakota lignite coal. The fly ash samples were obtained from a research project currently in progress at the EERC for the North Dakota Industrial Commission. Neither of the ash samples meets ASTM C618 specifications (Table 1) for use as a partial cement replacement in

TABLE 1

Testing of Fly Ash for Use as a Partial Cement Replacement in Concrete

Chemical Test Parameters	Fly Ash Sample No. 1	Fly Ash Sample No. 2	ASTM Specification if Applicable
SiO_2, %	29.9	29.1	---
Al_2O_3, %	11.4	13.1	---
Fe_2O_3, %	7.7	4.9	---
Total, %	49.0	47.1	50.0 min.
SO_3, %	7.04	6.33	5.0 max.
CaO, %	16.66	21.14	---
Moisture Content, %	8.40	0.10	3.0 max.
Loss on Ignition, %	3.43	0.38	6.0 max.
Available Alkali, %	3.63	4.30	1.5 max.
Physical Test Parameters			
Fineness on #45-μm Sieve, %	62.25	14.31	34.0 max.
Strength Activity Index, %			
@ 7 days	69	88	75 min.
@ 28 days	67	83	75 min.
Water Requirement, %	97	97	105 max.
Autoclave Expansion, %	0.20	0.18	0.80 max.
Specific Gravity	2.31	2.86	---

concrete so ultimately disposal would be the only alternative for both. Though several of the results given in Table 1 are quite acceptable for many applications for concrete, the fact remains that most transportation and construction engineers adhere closely to the guidelines listed in the ASTM C618 specification. Often even the slightest deviation from the required specifications would prevent acceptance for use as a partial cement replacement in concrete.

Evaluation of alternative test procedures was performed using the classification flowchart. The results of some of these procedures are given in Table 2. The grain-size distribution for most coal fly ashes shows a substantial portion of the material will be finer than the No. 200 sieve

TABLE 2

Additional Results of Fly Ash for Structural Fill Applications

Test Parameters	Fly Ash Sample No. 1	Fly Ash Sample No. 2
Moisture Density Relations		
Optimum Moisture Content, %	24.4	9.2
Maximum Dry Density, pcf	97.2	125.2
Grain Size Distribution		
D_{50}, μm	10	8
Uniformity Coefficient, D_{60}/D_{10}	4.3	5.5

(75 μm). The results of the two fly ash samples examined here bear this out. The small grain size will allow uniform compaction of a structural fill and reduce the chance of uneven bearing capacity of the fill. A typical requirement is that the fill be compacted to 90%–95% of the maximum dry density. Standard construction equipment will easily accomplish this method of compaction in the field. The desired performance of the site in terms of safe slopes and adequate performance of foundations, structures, and roadways will dictate the degree of compaction needed.

The moisture–density relationships are used to determine the handling and compaction efforts required to place the fly ash in a structural fill application. Depending on these characteristics, design engineers can determine the necessary volumes of dry materials that are needed for placement. More raw material of sample No. 2 would be needed to have an equal volume of sample No. 1 for a structural fill application. Likewise more water would be required for placement of sample No. 1 than what would be required for the other sample. Depending on the location of the construction site, these two variables could play a significant role in construction planning.

The grain-size distribution assists the engineers in determining the structural matrix on the compacted fill. The percent of raw material which is 50% finer than a certain sieve size (D_{50}) indicates the nominal particle size of a material. In this case, both samples are considered very fine-grained particles. The uniformity coefficient (C_U) gives an indication of the distribution of particle sizes. The C_U values here would indicate the fly ashes are poorly graded or in other words, there is not a wide range of particle sizes. The C_U values can also be used in empirical equations to give the engineer an idea of other characteristics of the compacted fill such as permeability. It is possible that the engineer may require additional raw materials, such as silty sand, to be blended with the fly ash to achieve a desired grain-size distribution. Of course, if additional materials are blended with a fly ash, then the other physical and chemical properties will be affected.

4.0 CONCLUSIONS

A flowchart was used to evaluate coal fly ash for use as a construction material in an application other than the traditional partial cement replacement in portland cement concrete. Two fly ashes, produced from lignite coal from North Dakota, were identified as potential candidates for use as a structural fill in embankments for roads or levees. Normally these two sources of coal ash are disposed in costly landfills or ponds. With the use of a classification flow chart, additional characteristics of the ashes were evaluated and assessed for alternative utilization. Both sources of fly ash would perform sufficiently in a structural fill application. If these materials were to be used for this application a more extensive evaluation would be required. With the additional characterization, more uses other than structural fill could be identified.